



# Strong, Ductile and Low-Field Magnetostrictive Alloys Based on Fe-Ga

PI: Sivaraman Guruswamy, University of Utah

DMR Award # 0241603

## Research Objectives

Magnetostriction refers to the change in the length of a material when a magnetic field is applied. Our earlier work made a significant discovery that the addition of nonmagnetic element Ga in Fe results in an order of magnitude increase in low field magnetostriction. FeGa alloys are strong and ductile, show low hysteresis, and are attractive for use as sensors and actuators.

Major objectives of current work:

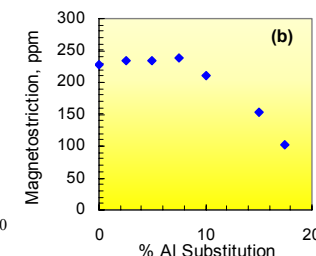
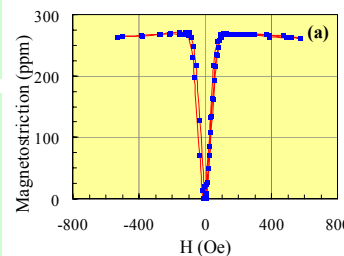
- Examine Fe-Ga based alloys and other Fe-based alloys containing additions that differ from Ga in their ground state electronic structure in order to better understand the magnetostriction phenomenon
- Develop a thermomechanical processing (TMP) scheme to obtain (001) textured FeGa alloys and examine the mechanism of texture evolution

## Technical and Scientific Impact

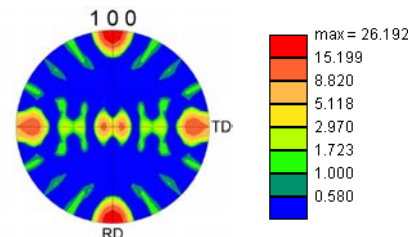
- Will provide an improved understanding of magnetostriction phenomenon
- Will lead to the development of low cost compositions with low hysteresis, low saturation field, and good mechanical properties, and amenable to low cost processing
- Technology developed will be used in numerous rugged defense and commercial sensor and actuator applications such as acoustic devices, MEMS devices, load sensors, anti-lock-braking systems, and active damping systems

## Significant Results

- Novel engineering applications of magnetostriction in Fe, Ni, and Co alloys developed and patent application filed.
- Hydrogen diffusion rates changed /controlled by the application of magnetostriction in Ni and Fe based alloys
- Large substitutions of Ga with cheaper Al can be made in Fe-20 at% Ga alloys while retaining large magnetostriction and optimal compositions identified.
- Inexpensive and simple large scale thermomechanical processing method developed for obtaining the desired strong [001] texture in polycrystalline Fe-15 at.% Ga alloys. Patent application to be filed.
- Magnetostrictions in DG grown Fe-X (X=Sn,Ge,Si, Zn, Mo,Be) and Fe-Ga-X (X=Al,Sn,Co,Ni,Ge,Si) alloys examined



Large magnetostriction in Directionally Grown (a) Fe-27.5 at.% Ga and (b) Fe-(20-x) at.% Ga-x at.% Al alloys



(001) Pole figure showing a very strong [001] texture in Fe-15 at.% Ga alloy obtained by Controlled Thermomechanical Processing



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#### Education and Training

- Four graduate students (Rob Corson, Pinai M., and P. Kumar, and T.V. Jayaraman) are now working towards their PhD. Robert and Pinai presented papers at the 2004 TMS Annual Meeting
- Undergraduate student Rebecca Chandler presented a poster paper on "The influence of ordering on magnetostriction" at the Univ. of Utah Undergraduate Research Conference and was a co-author of the paper presented at the TMS Annual Meeting
- Participating students are trained in advanced processing and characterization techniques including single crystal growth, OIM in SEM, TEM, XRD, magnetic and magnetostriction measurements, and Resonant Ultrasound Spectroscopy
- Students in Physical Metallurgy, Magnetic Materials, and Materials Design classes exposed to MML and ongoing research

#### Outreach Activities

- Robert Corson was selected as a member of the US student delegation to the 54<sup>th</sup> Annual Meeting of Students with the Nobel Laureates in Lindau Germany, held during June-July 2004
- The PI and the graduate students showcased the Magnetic Materials Laboratory to about 80 high school students and parents during the Departmental Open-house in 2003 and 2004
- Participated in the Innovation 2003 Showcase and Innovation 2004 Showcase meetings in Salt Lake City
- Invited paper on "Fe-based Low-Cost Magnetostrictive Alloys and Devices" presented at the Intl. Conf. "Advances in Materials & Processes for Industrial Applications ..." Pune, India, Sept., '03



Robert Corson attending the 54<sup>th</sup> Annual Meeting of Students with the Nobel Laureates in Lindau Germany, during June-July 2004



Rebecca Cook presenting a poster at the Undergraduate Research Conference



High School Students and their parents visiting the Magnetic Materials Lab.

#### Upcoming Publications

- Crystallographic Textures In Rolled And Annealed Fe-Ga And Fe-Al Alloys by N. Srisukhumbowornchai and S. Guruswamy, *Metallurgical Transactions*
- Rare-Earth Free Fe-Ga Based Magnetostrictive Alloys for Actuator and Sensors, S. Guruswamy, et al., *Trans. IIM- Special Issue on "Advances in Materials for Automotive Applications"*
- To be presented and appear in TMS 2005 Conf. Proceedings*
- Preparation and Evaluation of Magnetic Fe-Zn Alloys by Explosive Compaction by R. Corson et al.
- Magnetostriction and Magnetic Properties of PdX (X=Fe, Ni, Co) Single Crystals P. Kumar et al.
- Effect of Magnetic Field on the Permeation of Hydrogen in Ni and Fe alloys by S. Guruswamy et al.
- Four Other Papers